



NASA SBIR 2012 Phase I Solicitation

H8 High Efficiency Space Power Systems

This topic solicits technology development for high-efficiency power systems to be used for the human exploration of space. Power system needs include:

- Batteries for extravehicular activity suits.
- Electrical power for in-space propulsion systems.
- Electric power generation and energy storage for planetary and lunar surface applications.

H8.01 Fuel Cells and Electrolyzers:

- Ion-exchange membranes for PEM electrolyzers, emphasizing low acid generation to meet a critical ISS need and low permeability to increase the efficiency of high pressure systems for surface systems.
- Solid oxide fuel cell technology to spark the next-generation of fuel cell technology that will enable operation with multiple fuels including methane for landers and hydrocarbons generated from ISRU processes.

H8.02 Ultra High Specific Energy Batteries:

- Cathodes compatible with silicon-composite anodes to address the key obstacle to current lithium ion battery development for extravehicular activities.
- High-risk battery chemistries offering performance well beyond Li-ion.

H8.03 Space Nuclear Power Systems:

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- 10 kWe-class power conversion devices and 450K radiators to support the Technology Demonstration Unit for surface power and 100kW-class electric vehicles.
 - 100 kWe-class power conversion devices, > 500K radiators, and high temperature fuels, materials, and heat transport to support fission power systems for MW-class electric vehicles.
 - 1 kW-class fission power systems concepts to support science missions and small-scale surface power systems.

H8.04 Advanced Photovoltaic Systems:

- Solar cell, blanket, and interconnect technologies consistent with the needs of solar electric propulsion systems:
 - Flexible blankets.
 - High voltage and high power operation.
 - Low cost, high volume fabrication techniques.
- Modular panel concepts that emphasize low mass and cost reduction.

Subtopics

H8.01 Fuel Cells and Electrolyzers

Lead Center: GRC

Participating Center(s): JPL, JSC, KSC

Ion-Exchange Membranes for PEM Electrolyzers

During high-pressure electrolysis operation, hydrogen permeation through the ion-exchange membrane acts to reduce the current efficiency within the cell. This permeation increases with increasing pressure. Technological approaches are sought that significantly reduce this permeation. Areas of interest include:

- Demonstrated hydrogen permeability reduction >50% for Nafion membranes.
- Concurrent conductivity reductions
- Additionally, such membranes should have low acid generation rates to avoid degrading other elements within the cell stack, and must maintain good water transfer capability, bubble point, and tensile strength for use with cathode liquid-feed systems.

Solid Oxide Fuel Cell Systems

Technologies are sought that improve the durability, efficiency, and reliability of SOFC systems fed by oxygen and

fuels such as propellant-grade methane and those generated by ISRU systems (e.g., CO, syngas). Primary SOFC components and systems of interest:

- Power outputs in the 1 to 3 kW range.
- Offer thermodynamic efficiencies of 70% (fuel source-to-DC output) when operating at the current draw corresponding to optimized specific power.
- Operate as specified after at least 50 start-up cycles (from cold to operating temperature within 20 minutes) and 50 shut-down cycles.
- Operate as specified after at least 2500 hours of steady state operation on propellant-grade methane and oxygen. System should startup dry but after reaching operating conditions an amount of water/H₂ consistent with what can be obtained from anode recycle can be used. Amounts must be justified.
- Minimal cooling required as obtained by way of conduction through the stack to a radiator exposed to space and/or by anode exhaust flow.

Technology Readiness Levels (TRL) of 3 to 4 or higher are sought.

Potential NASA Customers include:

- International Space Station.
- Human Exploration and Operations Mission Directorate.

H8.02 Ultra High Specific Energy Batteries

Lead Center: GRC

Participating Center(s): JPL, JSC

Advanced rechargeable batteries are sought for future NASA missions.

For near-term missions, advanced lithium-ion (Li-ion) systems are being developed with the goal to achieve 265 Wh/kg and 675 Wh/L on a cell level. Advanced cathodes are sought, which when integrated into a full cell with a silicon-carbon composite anode, can enable a Li-ion cell to achieve the stated goals at practical voltage levels at a C/10 discharge rate when operating at 10 °C. The cathode should retain 80% of its initial capacity after 250 cycles. In addition, because the cathodes must be manufactured practically, cathodes must achieve a tap density of >1.5 g/cc, should possess qualities that can enable loading of at least 15 mg/square cm per side, and should utilize synthesis approaches that are readily scalable and are amenable to large scale electrode processing utilizing standard battery component equipment. The anode will achieve a reversible capacity of 1000 mAh/g and operate between 50 millivolts and 1 volt versus lithium. The cathode should have no detrimental impact on anode electrochemical performance, cycle-ability or cycle life, should possess a high degree of thermal stability, should

have low toxicity, and should be stable against typical carbonate-based electrolytes at voltage levels and material loadings that are practical for the proposed system.

For far-term missions, proposals are sought for advanced next generation rechargeable chemistries that go beyond Li-ion and have the potential to offer >500 Wh/kg and >700 Wh/L on the cell level. Advanced next generation chemistries will be required for human missions, therefore specific energy and energy density goals must be met while simultaneously delivering a high level of safety. Applications may include Extravehicular Activities (spacesuit) and robotic landers and rovers for missions to outer planets, moons and asteroids.

Phase I proposals must include analysis and numerical/quantitative evidence to justify the choice of cathode or advanced chemistry that clearly shows how the proposed component/system has the potential to meet the projected specific energy and energy density goals at the end of a Phase II effort. Additionally, Phase I proposals should describe the technical path that will be followed to achieve the desired specific energy and energy density.

Technology Readiness Levels (TRL) of 4 or higher are sought.

Potential NASA Customers include:

- *Technology is cross-cutting* – applicable to any mission or application that requires low mass, low volume, safe batteries. Some examples:
 - Office of Chief Technologist.
 - Human Exploration and Operations Directorate (EVA suits, landers, rovers, habitats, vehicle power).
 - Aeronautics Research Directorate (electric aircraft).
 - Science Directorate (power for payloads).

H8.03 Space Nuclear Power Systems

Lead Center: GRC

Participating Center(s): JPL, JSC, MSFC

NASA is developing fission power system technology for future space transportation and surface power applications using a stepwise approach. Early systems are envisioned in the 10 to 100 kWe range that utilize a 900 K liquid metal cooled reactor, dynamic power conversion, and water-based heat rejection. The anticipated design life is 8 to 15 years with no maintenance. Candidate mission applications include initial power sources for human outposts on the Moon or Mars, and nuclear electric propulsion systems (NEP) for Mars cargo transport. A non-nuclear system ground test in thermal-vacuum is planned by NASA to validate technologies required to transfer reactor heat, convert the heat into electricity, reject waste heat, process the electrical output, and demonstrate overall system performance. 1-10 kWe systems are also envisioned for power for robotic science missions to fill the

gap between radioisotope power systems and higher power systems.

The primary goals for the early systems are low cost, high reliability, and long life. Proposals are solicited that could help supplement or augment the planned NASA system test. Specific areas for development include:

- 10 kWe-class Stirling and Brayton power conversion devices.
- 450 K radiator panels with embedded heat pipes.
- Kilowatt-class fission power systems concepts and technologies

The NASA non-nuclear system ground test is expected to provide the foundation for later systems in the multi-hundred kilowatt or megawatt range that utilize higher operating temperatures, alternative materials, and advanced components to improve system performance. For the later systems, specific power will be a key performance metric with goals of 30 kg/kWe at 100 kWe and 10 kg/kWe at 1 MWe. Possible mission applications include large NEP cargo vehicles, NEP piloted vehicles, and surface-based resource production plants. In addition to low cost, high reliability, and long life, the later systems should address the low system specific mass goal. Proposals are solicited that identify novel system concepts and methods to reduce mass and increase power output. Specific areas for development include:

- 100 kWe-class Brayton and Rankine power conversion devices.
- Waste heat rejection technologies for 500 K and above.
- High temperature reactor fuels, structural materials and heat transport technologies.

Technology Readiness Levels (TRL) of 3 to 5 or higher are sought.

Potential NASA Customers include:

- The primary customer is the Office of Chief Technologist (OCT).
- Game Changing Development Program.
- Nuclear Systems Project.

Secondary customers include:

- Advanced Exploration Systems (AES) under the Human Exploration and Operations Mission Directorate.
- Planetary Science Division under the Science Mission Directorate.

H8.04 Advanced Photovoltaic Systems

Lead Center: GRC

Participating Center(s): JPL, JSC

Advanced photovoltaic (PV) power generation and enabling power system technologies are sought for improvements in capability and reliability of PV power generation for space exploration missions. Power levels for PV applications may reach 100s of kWe. System and component technologies are sought that can deliver efficiency, cost, reliability, mass and volume improvements under various operating conditions. Compatibility with solar cells having at least 29% efficiency and flexible blankets is required.

PV technologies must enable or enhance the ability to provide low-cost, low mass and higher efficiency for power systems with particular emphasis on high power arrays to support solar electric propulsion spacecraft operating at high voltage in the deep space environment. Technologies can address recurring and non-recurring costs for flight units or development units. Examples include technologies that reduce the solar cell cost, modular panel designs, automated blanket/cell/integration and interconnects, low cost/low mass coverglass/coatings, etc.

Areas of particular emphasis for 2012 include:

- Advanced PV blanket and component technology/ designs that support very high power and high voltage (> 200 V) applications.
- PV module/ component technologies that emphasize low mass and cost reduction (in materials, fabrication and testing).
- Improvements to solar cell efficiency that are consistent with low cost, high volume fabrication techniques.
- Automated/ modular fabrication methods for PV panels/ modules on flexible blankets (includes cell laydown, interconnects, shielding and high voltage operation mitigation techniques).

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

Technology Readiness Levels (TRL) of 2 to 6 or higher are sought.

Potential NASA Customers include:

- Solar Electric Propulsion Technology Demonstration Project in the Office of the Chief Technologist.
- Human Exploration and Operations Mission Directorate; Science Mission Directorate.

